ASSESSMENT OF CARPAL TUNNEL SYNDROME RISK AMONG DESIGNERS PERFORMING DIGITAL DESIGN ACTIVITIES

By

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Carpal tunnel syndrome (CTS) is a significant occupational disease among intense computer users such as designers and other professionals. Adverse musculoskeletal problems such as numbness, tingling, weakness or muscle injury in the hand and fingers can result from CTS. Designers are prone to CTS due to working for long hours nature in poor posture. The aim of this study is to determine risk of CTS among designers that working on design work digitally using computer in a cross-sectional study. A total of 225 designers who met the inclusion criteria participated in the survey that deployed Phalen's test to screened for CTS as well as Boston Carpal Tunnel Questionnaire (BCTQ). Rapid Office Strains Assessment (ROSA), NASA Task Load Index (TLX) and the Fuzzy Delphi method were among the instruments used in this study. Respondents included graphic, multimedia, industrial, automotive, interior, and computer aided design (CAD) designers, architects, and design engineers. The study found a prevalence of 20% of CTS among these designers. In this study, the following risk factors were associated with CTS: side job more than 6 hours per week (OR: 2.81, 95% CI 1.17-6.74) and graphic designers (OR: 2.08, 95% CI: 1.06-4.10). In this study designers' workplace was assessed using the Rapid Office Strain Assessment (ROSA), it was found that 58.82% of designers who participated in the assessment scored 5 or higher (ROSA) that indicates designers need to take ergonomic measures on the workstation in the future. In this study, designers with positive Phalen's test took Boston Carpal Tunnel Questionnaire (BCTQ) to accesses severity and symptoms of CTS that affecting these creative population. In terms of psychological risk, mental workload (MLW) was highest in this population, with a mean score of 63.48 for NASA TLX. A high value (> 60) was associated with mental workload in the post-test. The design task, which must be completed within a tight time frame, ranked first for "effort" in the pre-test and post-test, indicating that the design task requires both a physical and mental workload. The MWL result indicates that designers' unique way of working, which requires eustress to accelerate creativity, contributes to the risk of CTS. Carpal Tunnel Syndrome Risk Among Designers Model was established using multiple regression modelling in SmartPLS 4 in order to determine the relationship between work organisation (B=0.66,

T=2.81, P<0.05) and stress responses after work (B=0.28, T=3.56, P<0.05) factors with CTS outcome. The two predictors significantly predicted the outcome and both mentioned factors contribute 52.1% to risk of CTS in design population. The model was validated by eight experts using the fuzzy Delphi method and reached expert's consensus of 98% on all 14 items. The experts agreed that stress responses after work was significantly reflects the risk factor of design population in this study. The experts agreed that the model suitability to be used as guide for designers and employers to educate and spreading awareness to employers and designers on risk of CTS. Stress responses after work factor that consist of more than 6 hours of side job a week variable, was both found significantly associated with both MLR and Regression model. Therefore, it can be concluded that more than 6 hours of side job in a week is the significant risk factor among within design community where it's become novelty of this research. Raising awareness among designers is important to protect their talented hands, because hands are another asset of these professionals, along with their creative minds. This research could lead to a better understanding of the unique relationship between designers' practises and the risk of CTS for future prevention planning.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN RISIKO SINDROM TROWONG KARPAL DIKALANGAN PEREKA YANG MENJALANKAN AKTIVITI SENIREKA DIGITAL

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Sindrom terowong karpal (STK) adalah penyakit pekerjaan yang ketara dalam kalangan pengguna komputer secara maksimum seperti pereka dan profesional lain. Antara gejala muskuloskeletal yang disebabkan oleh STK adalah seperti kebas, kesemutan, lemah atau kecederaan otot di tangan dan jari. Pereka bentuk terdedah kepada STK kerana bekerja untuk waktu yang lama dalam keadaan postur yang tidak ergonomik. Kajian ini bermatlamat untuk mengukur, mengkaji dan mengenal pasti risiko sindrom terowong karpal (STK) dalam kalangan pereka yang menjalankan kerja reka bentuk secara digital menggunakan komputer dalam kajian keratan rentas ini. Sebanyak 225 pereka yang memenuhi kriteria inklusif menyertai tinjauan yang menggunakan ujian Phalen untuk saringan STK selain Boston Carpal Tunnel Questionnaire (BCTQ). Rapid Office Strains Assessment (ROSA), NASA Task Load Index (TLX) dan kaedah Fuzzy Delphi juga merupakan instrumen-instrument lain yang digunakan dalam kajian ini. Responden termasuk pereka bentuk grafik, multimedia, perindustrian, automotif, pereka dalaman dan pereka komputer data (*Computer Aided Design* (CAD)), arkitek dan jurutera reka bentuk. Kajian itu mendapati 20% prevalens daripada STK di kalangan pereka bentuk dalam kajian ini. Faktor risiko yang dikenalpasti dalam model multiple regression (MLR) adalah: kerja sampingan lebih daripada 6 jam seminggu (OR: 2.81, 95% CI 1.17-6.74) dan pereka grafik (OR: 2.08, 95% CI: 1.06-4.10). Dalam kajian ini tempat kerja pereka telah dinilai menggunakan Rapid Office Strain Assessment (ROSA), didapati 58.82% pereka yang menyertai penilaian mendapat markah 5 atau lebih tinggi (ROSA) yang menunjukkan pereka perlu mengambil langkah intervansi ergonomik pada stesen kerja untuk masa depan. Dalam kajian ini, pereka bentuk yang positif ujian Phalen telah mengambil ujian Boston Carpal Tunnel Questionnaire (BCTQ) untuk menilai tahap keseriusan dan gejala STK yang mempengaruhi populasi kreatif ini. Dari segi risiko psikologi, beban kerja mental (BKM) didapati pada skala tinggi dengan min 63.48 untuk skor NASA TLX dalam populasi ini. Skor tinggi (> 60) dikaitkan dengan beban kerja mental dalam ujian pasca. Tugas reka bentuk yang mesti diselesaikan dalam tempoh masa yang diberikan mendapati "usaha" menduduki tempat pertama dalam ujian pra dan ujian pasca. Ini memberiki indikasi bahawa tugas reka bentuk memerlukan beban kerja

fizikal dan mental. Keputusan BKM menunjukkan bahawa cara kerja unik pereka, yang memerlukan eustress untuk menjana kreativiti sekali gus menyumbang kepada risiko STK. Model Risiko Sindrom Trowong Karpal di Kalangan Pereka telah dihasilkan menggunakan kaedah Model Regrasi di dalam perisian SmartPLS 4 untuk menentukan hubungan antara faktor organisasi kerja ($B=0.66$, $T=2.81$, $P<0.05$) dan tindak balas tekanan selepas bekerja ($B=0.28$, $T=3.56$, $P<0.05$) dengan dapatan risiko STK. Kedua-dua peramal dengan ketara meramalkan hasil dan kedua-dua faktor yang disebutkan menyumbang 52.1% kepada risiko STK dalam populasi pereka. Model ini telah disahkan oleh lapan pakar menggunakan kaedah Fuzzy Delphi dan mencapai konsensus pakar sebanyak 98% pada kesemua 14 item. Pakar bersetuju bahawa tindak balas tekanan selepas bekerja secara signifikan mencerminkan faktor risiko populasi reka bentuk dalam kajian ini. Pakar juga bersepakat bahawa kesesuaian model itu digunakan sebagai panduan bagi tujuan kesedaran dan pendidikan kepada pereka dan majikan terhadap risiko STK. Tindak balas tekanan selepas faktor kerja dengan pembolehubah tunggal iaitu lebih daripada 6 jam kerja sampingan dalam jangkamasa seminggu, didapati signifikan dengan kedua-dua model MLR dan model regresi. Oleh itu, boleh disimpulkan bahawa lebih daripada 6 jam kerja sampingan dalam seminggu adalah faktor risiko yang ketara dalam kalangan komuniti pereka di mana ia menjadi sesuatu yang baru dalam penyelidikan STK. Meningkatkan kesedaran dalam kalangan pereka adalah penting untuk melindungi tangan pereka. Ini kerana tangan adalah satu lagi aset terpenting seorang pereka selain daripada minda yang kreatif. Hasil penyelidikan ini boleh membawa kepada pemahaman yang lebih baik tentang hubungan unik antara amalan kerja pereka dan risiko STK untuk membolehkan kesedaran dan perancangan intervansi ergonomik bagi megurangkan risiko STK dikalangan pereka.

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LIST OF ABBREVIATIONS

CTS	Carpal Tunnel Syndrome
10th MP	Tenth Malaysia Plan
3D-PAT	3D Posture Analysis Tool
BCTQ	Boston Carpal Tunnel Questionnaires
CAD	Computer Aided Design
CMDQ	Cornell Musculoskeletal Discomfort Questionnaire
CPD	Continuing Education Hours
CVS	Computer Visual Syndrome
DOSH	Department Of Occupational Safety And Health
ECR	Extensor Carpi Radialis
ECU	Extensor Carpi Ulnaris
EDC	Extensor Digitorum Communis
EF	Effort
EMG	Electromyography
FDM	Fuzzy Delhi Method
FDS	Flexor Digitorum Superficialis
FMA	Factory And Machinery Act 1967
FPL	Flexor Pollicis Longus
FR	Frustration
HF	Head Flexion
ICU	Intensive Care Unit
ILO	International Labour Organization
MBOD	Malaysia Board Of Technologist
MD	Mental Demand
MLR	Multiple Linear Regression

MPS	Monitor Placement Model
MSD	Musculoskeletal Disorders
MWL	Mental Workload
NASA TLX	Nasa Task Load Index
NCS	Nerve Conduction Study
PD	Physical Demand
PE	Performance
PQ	Pronator Quadrates
PRISMA	Preferred Reporting Items For Systematic Reviews And Meta-Analyses
R&D	Research And Development
ROSA	Rapid Office Strain Assessment
RSI	Repetitive Strain Injury
RULA	The Rapid Upper Limb Assessment
SEM	Structural Equation Modelling
SLR	Simple Linear Regression
SOCSO	Social Security Organisation
TD	Temporal Demand
UiTM	Universiti Teknologi Mara
UPM	Universiti Putra Malaysia
UQMP	Upper Quadrant Musculoskeletal Paint
VIF	Variance Inflation Factor
WRMSDs	Work Related Musculoskeletal Diseases
WRULDs	Work Related Upper Limb Disorders

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Carpal Tunnel Syndrome (CTS) is one of the significant musculoskeletal disorders (MSD) which affects 3.3–3.5 people out of every 100 each year and has a prevalence rate of 1–5% in the general population (Hulkkonen et al. 2020). This may occur as a result of an unfavourable working environment and certain tasks that have to be performed by certain people. If the condition persists over a long period of time, the situation may worsen. CTS can also lead to workers becoming exhausted and unable to work, which in turn to lower productivity in the workforce.

The exertion of significant pressure on the median nerve, which results in tissue swelling around the carpal tunnel area, is thought to be the cause of the development of CTS. CTS causes tissue swelling as a result of the intense pressure on the median nerve for instance from repetitive strains injury (RSI). Unwanted musculoskeletal issues like numbness, tingling, weakness, or muscular injury on the hand and fingers can result from CTS. CTS can also cause fatigue and impairment in workers, both of which lower productivity, as the muscles in the hands and fingers can become weak, numb, tingly or damaged by CTS. The risk of developing CTS is greater in jobs that need continual, strong hand and wrist motions (Toosi et al. 2015).

Financially, CTS patients must take numerous sick days, which raises healthcare costs significantly (Hulkkonen et al. 2020). The healthcare expenses associated with CTS treatment and the productivity loss from sick time cause the organisations to bear a significant financial burden. Up to 9.5 million workdays were lost as a result of MSD cases, including CTS, according to the British Labour Survey (2015), which translates to an average of 17 days per person (Executive, 2019). Organizations that have a high absenteeism rate suffer financially due to sick leave fees and staffing constraints. At the office, workload bottlenecks lead to a loss in productivity, which in turn raises workplace stress levels. Workers with MSDs diseases like CTS require at least 13 days to return to work, according to a prior report (National Institute for Occupational Safety and Health 1997). Staff shortages make it impossible to complete tasks by the due date, resulting in a loss of income for the organisation.

Number of researches have examined the relationship between computers usage at work and musculoskeletal conditions namely CTS (Ardahan and Simsek 2016; Baba et al. 2016; Huysmans et al. 2018; Labbafinejad et al. 2019; Schmid et al. 2015). When doing computer-aided data entry, text processing, and mouse operation, uncomfortable hand and arm positions might contribute to MSD including repetitive strain injury (RSI). High levels of static muscle activity and severe postures including wrist extension, ulnar deviation, and shoulder abduction have been linked to RSI from mouse use (Onyebeke et al. 2014).

1.1.1 MSD & CTS in Malaysia

In Malaysia MSD and CTS were diseases that insured by The Social Security Organisation (SOCSO) of Malaysia. In the statistic figure 1.1 mentioned that one-quarter of industrial workers suffered from upper limb injuries (Tengku Zawawi et al. 2018). SOCSO classifies hearing loss, musculoskeletal disorder, vibration problems, skin conditions, and occupational asthma as occupational diseases. Industrial accidents now account for the majority of occupational injuries and impairments, accounting for 57,639 cases in 2017 compared to 55,186 cases in 2016 as listed in Figure 1.1. Both moderate and severe illnesses fall under the categories of MSD cases. Carpal Tunnel Syndrome contributed to 24 percent of all MSD cases reported by SOCSO between 2006 and 2010 as in Figure 1.2 below. It was listed that CTS as Malaysia's second-most common occupational ailment with 24% prevalence from reported work related musculoskeletal disease (WRMSDs) (Rasib 2019).

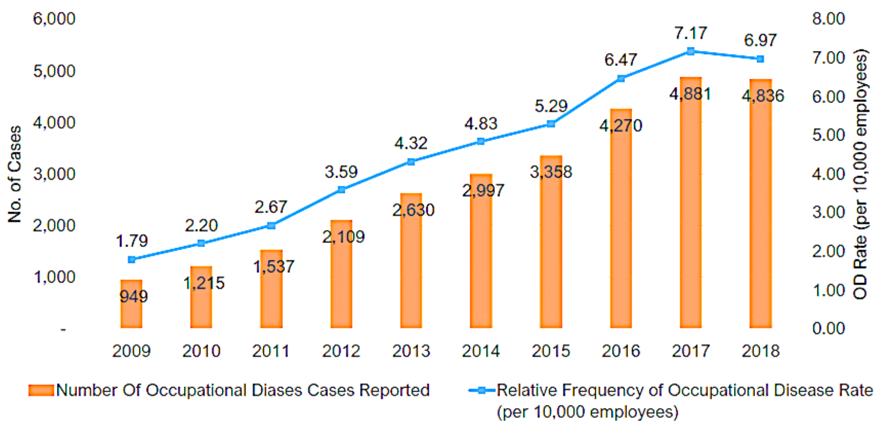

Figure 1.1 : Occupational Diseases Graft from 2009 to 2018
(Adapted from SOCSO Malaysia, 2019)

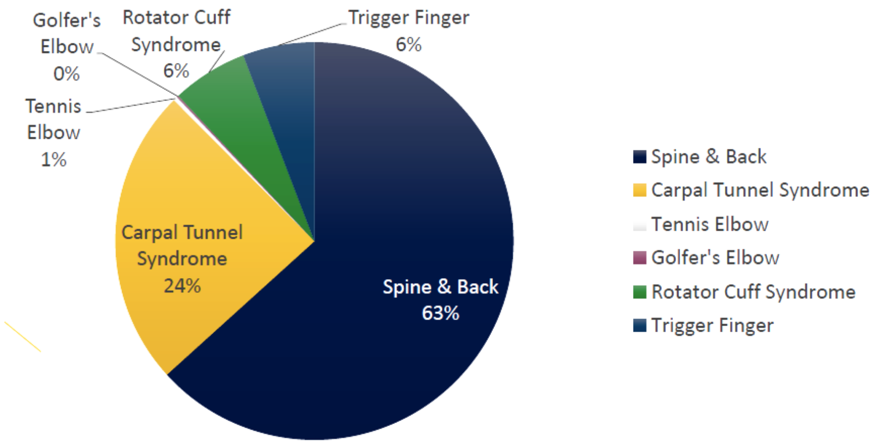

Figure 1.2 : WRMSDs Pie Chart by Diseases
(Adapted from SOCSO, 2009)

The prevalence of MSDs and CTS in Malaysia has been significantly associated with the manufacturing sector (Tan et al. 2015; Tengku Zawawi et al. 2018), where work-related musculoskeletal disorders (WMSDs) typically occur. WMSDs are among the most common RSI carpal tunnel syndromes (CTS) and associated risk factors among assembly line workers in traditional and semi-ergonomic shock manufacturing. The repetitive nature of assembly line work and its activities lead to WMSDs (Nazmi et al. 2016).

Computer use has also been found in many studies linking different occupations to factors influencing the incidence of musculoskeletal disorders lead to CTS in Malaysia. Studies conducted in Malaysia on computer workstations in the government (B.M.Ta et al. 2009) and private (Baba et al. 2016; Tamrin and Zakaria 2016) sector found positive cases mainly due to RSI from long computer working hours. According to the study done by Baba et. al. (2016) there is a significant association between the prevalence of RSI and workplace design in the office work atmosphere in Malaysia. In addition long periods in awkward or uncomfortable position, sedentary and static work and long hours of computer usage were highlighted as risk factors for MSDs and CTS (Baba et al. 2016).

1.1.2 Design Professionals

Designers, architects and design engineers who work with computers are a group of imaginative people whose job it is to turn ideas into tangible products such as books, furniture, houses or even aeroplanes (Dogru, 2015). Design experts traditionally create and finish their artworks by hand utilising drawing supplies such a drawing board or table, a T-square, pens, pencils, colour pencils, marker pens, and other design materials (Wilkinson, 2008). When that happens, a designer's desk is typically piled high with sketching paper, markers, or a lump of dried graphic glue that may double as a stress ball or an eraser. With the advent of the digital era after the 1970s, numerous works of art began to be produced professionally with the use of computers (Tornincasa and Torino 2010).

Professional designers have access to computers that allow them to transfer their thoughts into digital form before delivering the finished product. Professional designers and computers are essentially interwoven in today's current world of design. Although early design ideas are still developed using manual sketches, the computer has evolved into a crucial tool in the design process. Design experts who worked on digital artwork for extended periods of time on computers without ergonomics features risk suffering major illnesses such as CTS and MSDs (Faraji and Farahmand 2013). Design professionals typically work from nine to five, making them frequent computer users (Faraji and Farahmand 2013). In order to adhere to the project timeline or industrial production lines, they are also obliged to respect the deadlines set by the clients. Before being transformed into data or soft copy form during the final design step, the majority of artworks begin as straightforward hand sketches. As a result, many designers spend most of their working hours in front of computers.

A study conducted by Justice (1990) in the 1990s during the early adoption of the Macintosh in design offices and agencies in the United States of America found a risk of musculoskeletal disorders lead to CTS when working at a computer for only 4 to 5 hours a day (Justice 1990). 77% of respondents reported physical pain, including hand and wrist pain, general fatigue and headaches. The 2019 survey of designers in the United States found that designers' work hours continue to increase, with the majority working between 40 and 50 hours and some working up to more than 60 hours per week (American Institute of Graphic Arts 2019). Almost all designers were found to have a side job after their normal working hours, usually related to a paid design job or purely for charity. These secondary activities or side job were also found in the study conducted by Sahu et. al (2019) in India among CAD designers (Sahu et al. 2019). The designers who were associated with risk of MSDs were found continued to work on computers after returning home from work. These scenarios may highlight the risk of CTS and MSDs in this group of designers, which need to be investigated further.

Despite the fact that the modern labour market advocates for a work-life balance to enhance quality of life, (Mohd Kasmuri et al. 2020) this group of professionals only sees the concept of a balanced lifestyle as hyperbole. In order to fulfil deadlines, designers frequently work long hours and stay late at the workplace. Designers has been trained since their college or university days in conditioned to such lengthy working hours in order to get ready for the demanding design world. Up to 74% of full-time employed design professionals in the United States of America put in between 40 and 50 hours each week for work (American Institute of Graphic Arts 2019). In connection with this, a different study revealed a higher chance of getting WMSDs when using computers for more than 20 hours per week and a higher risk of developing CTS when using computers for more than 30 hours per week (Faraji & Farahmand, 2013). Given how many design professionals work long hours, occupational health problems are probably prevalent among them

1.2 CTS & Ergonomics Policies in Malaysia

In Malaysia, the Department of Occupational Safety and Health (DOSH) combats musculoskeletal disorders and related diseases such as carpal tunnel syndrome with a heightened awareness of ergonomics in the workplace. Ergonomics is one of the key elements for the effectiveness of health and safety legislation. Due to concerns about ergonomics and in support of key legislation, guidelines for assessing ergonomics risks in the workplace were produced in 2017 (Department Of Occupational Safety And Health, Ministry Of Human Resource 2017). This will be a good platform to introduce guidelines on ergonomics in the field of professional computer users such as designers, engineers and architects, continuing the efforts to highlight DOSH as a regulatory body for ergonomics laws.

The idea of designers being associated with workplace ergonomics was not new to the FMA in 1957. Regulation 30 (1) stipulated that in every factory where persons employed have in the course of their employment, reasonable opportunities for sitting without detriment to their work, there shall be provided and maintained suitable and sufficient seating facilities for their use (FMA 1967, 2013). The Occupational Safety and Health Guidelines for Seating at Work was established in 2002. The guidelines explain the occupational safety and health requirements for appropriate seating to reduce risks such as back pain. In section 7.3, the guideline highlights the sitting position requirements for workers classified as precision workers. The guideline mentions that Instrument engineers, laboratory technicians and draughtsmen are among the workers who tend to lean forward and adopt a tense posture. This tense posture has been linked to increased back, shoulder or neck pain. Guidelines recommend an adjustable backrest for this group of workers. The efforts are scientifically unsound (Rozlina et al. 2012) in certain workers group such as professionals.

1.2.1 Department of Occupational Safety and Health (DOSH)

In Malaysia, the Department of Occupational Safety & Health (DOSH) manages occupational safety and health, including ergonomics rules and regulations under Factory and Machinery 1967 (FMA 1967) and Occupational Safety and Health Act 1994 (OSHA 1994). Regulations, guidelines and codes of practice have been established and enforced by DOSH to support and compliment the Acts (Sirat et al. 2011). DOSH has established numbers of initiatives trough guidelines to regulate and cultivate ergonomics alertness among workers as listed below:

- Guidelines for Manual Handling at Workplace 2018;
- Guidelines for Manual Handling at Workplace 2018;
- Guidelines on Occupational Vibration, 2003;
- Guidelines on Occupational Safety and Health for Seating at Work, 2003;
- Guidelines on Occupational Safety and Health for Working with Video Display Unit (VDU's), 2003; and

- Guidelines on Occupational Safety and Health for Standing at Work, 2002.

Awareness of ergonomics plays an important role in implementing human well-being with safety in mind. Ergonomics creates conducive and comfortable working environments with ergonomically designed tools and a man-machine interface that harmonises the working method with the human anatomy (Rozlina et al. 2012). Section 4 of the Occupational Health and Safety Act 1994 states that one of the objectives of the Act is to "promote a working environment for persons at work which is adapted to their physiological and psychological needs". This important objective illustrates the strong synergy between ergonomics and occupational health (Sirat et al. 2011).

However, according to study done by Rozlina et. al, 2012, the role of DOSH in implementing the ergonomics regulations was vague. The study claims that unlike safety issues, there are unclear guidelines for ergonomics practises in general. Action needs to be taken to highlight the core of ergonomics practises legislation (Rozlina et al. 2012). This statement is supported by the study of Sirat et. al. (2011), which states that the role of ergonomics in OSH legislation is not consistently considered or widely appreciated.

1.2.2 Malaysia Board of Technologist (MBOT)

Malaysia Board of Technologist (MBOT) was established in 2015 under the Technologists and Technicians Act 2015 (Act 768) in line with the Tenth Malaysia Plan (10th MP) which emphasised the need to establish a professional body to recognise graduates and professionals in the fields of technology and engineering (Technologists 2018). MBOT has identified 23 technology and engineering fields that encompass a wide range of conventional occupations and disciplines. Art design and creative multimedia is one of the technology areas regulated under MBOT, which covers the processes, techniques and use of technology to produce creative content. This newly introduced law that recognises design professionals is the best platform to enshrine the guidelines set out in Section 6 (1) of Act 768 of 2015, which gives the power to regulate the conduct and ethics of technologists.

MBOT is a learning platform for members to improve their skills to venture into the dynamic field of different technologists that is constantly evolving (Technologists 2018). Using Continuing Professional Development (CPD) points under section 25 (1) of Act 769, raising awareness of CTS can become one of the essential subjects that can be offered under the CPD programme. As the risk of MSDs and CTS can be reduced through education, MBOT is a perfect platform to spread awareness.

1.2.3 Board of Architect, Malaysia

Board of Architects, Malaysia integrated with three (3) components of design namely interior designer, architect and building draughtsman professionals under The Architects Act 1967 (Act 117) (Attorney General Chambers of Malaysia 2015). This established professional bodies have been handling training and development program to enhance the skills and knowledge of the members.

The Architects Regulations 1996 require registered draughtsmen, qualified architects and architects to exercise the reasonable skill and care generally expected and recognised in the field. CPD have been defined as a lifelong learning process that maintains, enhances or improves the knowledge and skills of architects, graduate architects and registered draughtsmen to ensure that their knowledge and skills meet the needs of society, according to the Board of Architects Malaysia. As mentioned in MBOT section, CPD of Board of Architects Malaysia could be a platform to spread awareness of CTS risk among architects that registered with the board.

1.3 Problem Statements

Many previous studies have reported an association between CTS and office workers with long hours of computer usage in various industries (Mohamad et al. 2010; Sahu et al. 2019; Shariat et al. 2018). Since the 1970s, with the advent of automation technology, computers have become an integral part of business life in many industries (Wilkinson 2008). The use of computers is widespread throughout the world and both office workers such as data entry clerks and professionals spend most of their working time in front of a computer.

Mouse use is associated with high levels of static muscle activity and extreme postures, including shoulder abduction, wrist extension and ulnar deviation (Onyebeke et al. 2014). Awkward hand and arm posture during computer-aided data entry and word processing and mouse operation contributes to musculoskeletal disorders (MSDs) such as repetitive strain injury (RSI) syndrome, which can develop into CTS (Kluth and Keller 2015). Two thirds of typical computer work involves the use of the mouse, and for professionals the use is even more extensive due to long hours of computer exposure (Onyebeke et al. 2014). The combination of awkward posture and long hours of sitting while working with computer work were likely reflected to risk of MSDs and CTS within this creative population.

Digital design activities among designers starts in a very early stage of design process. The digital design activities of designers start at a very early stage of the design process. In the automotive industry, for example, digital design activities begin with the drafting of a mood board for each selected design concept (Tovey, Porter, and Newman 2003). Concept designs in automotive industry are known as computer-aided styling (CAS) (Bae and Kijima 2003). Currently, 2D raster-type graphics software such as SketchsPro is used for the ideation and design phase, while reverse engineering type software (CAD) such as Catia is used for the detailed design phase (Bae and Kijima 2003).

Since early introduction of computer usage in design industry the prevalence of MSD that lead to CTS was present in 4 to 5 hours of computer work daily. Designers these days works longer hours up to 40 to 60 hours a week. Working long hours at was not only alaring factor to these designers. According to a recent survey conducted by the

American Institute of Graphic Arts (2019) with a sample size of 9429 designers, almost all designers have side job after the normal working hours (American Institute of Graphic Arts 2019) . Designers nowadays then to continue working with computer at home instead of resting after long hours at work. As mentioned, scholar that working more than 30 hours a week with computer will elevated risk of CTS, the design population meets the vulnerable criteria to develop risk of CTS and therefore it is essential to evaluate the risk of CTS among designers.

The healthcare, construction, automotive and office work sectors formed the majority of participants in empirical research at CTS from previous literature (Boschman, Frings-Dresen, and Van Der Molen 2015; Shariat et al. 2018; Vujica Herzog et al. 2014; Wanberg, Caston, and Berthold 2019). However, there is still a very small number of studies among professionals who work frequently and extensively with computers, such as designers, architects and engineers. It is crucial to assess the risk of CTS in this group of designers, as the risk of CTS is not only a health or physical problem for the designers but could also affect them psychologically.

1.4 Study Justification

Designers are considered to be extensive users of computers within typical 9-5 working hours. Meeting deadlines is part of the daily work of designers, who need not only design skills but also concentration to complete their tasks. Some designers that are so driven with deadline were often not observed breaks between job. This habit were widely observed in graphic design community (Tunmibi, Ijeoma, and Sanusi 2012) that have more frequent and tight deadlines usually in arts industries such in publishing and advertising.

Sitting for long periods to meet deadlines could contribute to ergonomics problems in this creative population. Unergonomics chairs and workstation that did not match population’s anthropometric were issues that was found in MSDs studies in Malaysia (Baba et al. 2016; Mohamad et al. 2010; Mohd Yusoff et al. 2016). As for designers, they have to adopt an awkward posture when designing because some of the major design programmes such as Adobe Photoshop and Illustrator require designers to sketch and render their designs using the mouse as an input device. Sketching with the mouse mainly requires a more rigid hand movement, clicking and dragging the mouse all at once. It is therefore necessary to assess and observe designers' workplaces to observed for ergonomics hazards.

Designers have a variety of ways to earn extra money outside their regular working hours, because the position requires not only competence but also talent. Designers, whether they are full-time or self-employed, are often approached about taking on additional design work after their regular working hours. Therefore, many designers continue to work at home on the computer after their regular working day. (Sahu et al. 2019). Tight deadlines force designers to work as many computer hours as possible every day to complete the work before the deadline.

Chasing deadlines is part of the lifestyle of designers, where not only speed but also a creative mind is required to get the job done. Both the physical and mental aspects are required in design tasks that need to be completed within a certain time frame. The combination of the two can lead to work fatigue, which in turn can led to conditions such as RSI, that lead to CTS due to extensive used of the mouse for instance (Faraji and Farahmand 2013).

CTS risks among these designers are very high because of the long working hours dealing with computers. The creative mind of designers requires the coordination of their hands, which are undoubtedly their most important asset. Therefore, this study is crucial to educate these designers about the dangers of musculoskeletal disorders such as CTS, as these disorders can adversely affect their careers. Therefore, the absence and lack of CTS evidence among designers is a research gap that needs further investigation.

1.5 Objective

1.5.1 General Objectives

To study the risk factors of carpal tunnel syndrome among designers during performing digital design activities.

1.5.2 Specific Objectives

1. To determine the prevalence and risk factors of CTS among designers;
2. To evaluate risk of workstation design and work factors with CTS among designers with CTS symptoms;
3. To measure risk of physical symptoms and mental workload among designers with CTS symptoms; and
4. To develop a comprehensive model to assess the risk of CTS among designers with expert's consensus**.**

1.6 Research Question

1.6.1 Research Question for Objective 1

1. What is the prevalence of CTS among designers?
2. What are the risk factors of CTS among designers?

1.6.2 Research Question for Objective 2

1. Does workstation and equipment used by designers anthropometrically matched?
2. Do designers suffer from unergonomic workstation design?

1.6.3 Research Question for Objective 3

1. Does CTS symptoms effect daily life activities?
2. Does having CTS symptoms affected designers mentally?

1.6.4 Research Question for Objective 4

1. What are the variables of risk factor of CTS among designers?
2. What are the significant risk associated with CTS among designers?
3. What is the expert's agreement on the model proposed?
4. What is the expert's agreement on the usability of the proposed model?

1.7 Hypothesis

From Ergonomics and human factor points of view:

1. There is significant association between CTS and design population.
2. There is significant association between CTS and demographic factor.
3. There is significant association between CTS and working condition factor of designers.
4. There is significant association between CTS and side job factor.

1.8 Organisation of the Thesis

The thesis will be organised according to chapter stated below:

1.8.1 Chapter 1

Chapter 1 will contain an introduction to CTS in general. This chapter will also describe the designers whose work may be associated with the risk of developing CTS. This chapter will also set out the main aim and specific objectives and the related research questions. The research hypothesis is also mentioned in this chapter.

1.8.2 Chapter 2

Chapter 2 contains a review of all the literature related to this study. In this chapter, a systematic literature search was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method to collect all articles related to the keywords of this study. The underlying theories and models that guide the development of the theoretical model are also included in this chapter.

1.8.3 Chapter 3

Methodology of this research will be included in chapter 3. Research design, sample size will be spell out in this chapter. Test that will be used to determine CTS symptoms will be mentioned together with all methods and established questionnaires that will be used in order to achieve all the specific objectives.

1.8.4 Chapter 4

Chapter 4 presents all the results of the tests, assessments and models carried out in this study. This chapter also discusses all the results to provide a better understanding of the research.

1.8.5 Chapter 5

The final chapter of this thesis is Chapter 5, which contains a summary and conclusion of the entire study. The conclusion summarises the relationship between the results of all the objectives, which highlights the novelty of the study. This chapter also lists the future studies that could continue the research to bring more benefits to the design population.

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